Incorporating Daily Real-Time NESDIS/VIIRS Green Vegetation Fraction Data into the NOAA/STRC Environmental Modeling System (EMS)

(A supplemental instructions document for EMS v3.4.1+ users)

Author: Jonathan L. Case (ENSCO, Inc./NASA SPoRT), 22 May 2015

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1. Conventions and notations
   - Filenames are given by *italics,*
   - Executable programs/commands are in **bold type,**
   - Directory path locations are underlined,
   - $EMS is the top-level EMS installation directory
   - <domain> is the name of the EMS run domain of interest, located in $EMS/runs

2. Brief product background information: In mid-February 2015, NOAA/NESDIS promoted their daily real-time, global 4-km green vegetation fraction (GVF) product to operations on the NOAA Comprehensive Large Array-data Stewardship System server. The NESDIS real-time GVF product is derived using enhanced vegetation index composites from the Suomi-NPP/VIIRS instrument, and represents the fraction of photosynthetically active green vegetation at a given pixel. Additional details on the product can be found in the applicable 2013 AMS and 2015 NWA poster presentations (Vargas et al. 2013; Case et al. 2015). NASA/SPoRT has developed a process for ingesting these data into the EMS for use in the Weather Research and Forecasting (WRF) numerical weather prediction model, as outlined below. Use of this product replaces the default coarse-resolution monthly climatology of GVF. This methodology to incorporate VIIRS GVF into the EMS is similar to that used for the SPoRT MODIS GVF product (Case et al. 2014) in a previous supplemental instructions document for the EMS.

3. Assumptions: The instructions outlined below assume that the EMS user already has created a domain that is being used to generate WRF model simulations. It is also assumed that the end-user has a working knowledge of the EMS and can navigate through the EMS directories, configure a modeling domain, and set up various run-time and post-processing options. The only aspect of an EMS domain that is being modified is the static netcdf file(s) that define the input fields that do not vary during a WRF model simulation (e.g., *geo_em.d01.nc*, *geo_nmm.d01.nc*). These files reside in the static/ sub-directory for any given EMS run domain (e.g., $EMS/runs/<domain>/static/).

Specific instructions:

4. Configure EMS to accept daily NESDIS/VIIRS GVF files
    a. Change directory to $EMS/data/geog and create a new directory called greenfrac_viirsgvf:
        i. **cd $EMS/data/geog**
        ii. **mkdir greenfrac_viirsgvf**
    b. Create or acquire the file *index* from NASA/SPoRT and place it in the $EMS/data/geog/greenfrac_viirsgvf directory, with the following contents:

```
type=continuous
projection=regular_ll
dx=0.036
dy=0.036
known_x=1.0
known_y=1.0
known_lat=-89.982
known_lon=-179.982
wordsize=1
missing_value=0.
tile_x=10000
tile_y=5000
tile_z=12
tile_bdr=0
scale_factor=0.01
units="fraction"
description="Monthly green fraction"
```

    c. Modify the appropriate GEOGRID.TBL file, based on the dynamical core being run
        i. Make a backup copy of the *GEOGRID.TBL.ARW* or *GEOGRID.TBL.NMM* file, located in $EMS/data/tables/wps
        ii. Edit *GEOGRID.TBL.ARW or GEOGRID.TBL.NMM* to modify the GREENFRAC block:

```
==============================
name=GREENFRAC
priority=1
    dest_type=continuous
    interp_option=viirsgvf:four_pt+average_4pt+average_16pt+search        (← add this line)
    interp_option=modis_fpar:four_pt+average_4pt+average_16pt+search
    interp_option=default:four_pt+average_4pt+average_16pt+search
    z_dim_name=month
    masked = water
    fill_missing = 0.
    rel_path=viirsgvf:greenfrac_viirsgvf/                                 (← add this line)
    rel_path=modis_fpar:greenfrac_fpar_modis/
    rel_path=default:greenfrac/
==============================
```

5. Acquire daily VIIRS GVF data file
    a. New data are typically posted by 1200 UTC each day at ftp://geo.msfc.nasa.gov/SPoRT/modeling/viirsgvf/global/
    b. The most recent file is named *00001-10000.00001-05000.bz2* and will be approximately 60–70 MB in size.
    c. Acquire file via ftp session:
        i. **cd $EMS/data/geog/greenfrac_viirsgvf**
        ii. **ftp geo.msfc.nasa.gov** (user: anonymous; password: <your email address>)
        iii. **cd SPoRT/modeling/viirsgvf/global**
        iv. **bin**
        v. **get 00001-10000.00001-05000.bz2**
        vi. **bye**
    d. Uncompress newly acquired SPoRT GVF file
        i. **cd $EMS/data/geog/greenfrac_viirsgvf**
        ii. **bzip2 -d 00001-10000.00001-05000.bz2**
        iii. The file will uncompress to a size of 600 MB

6. Backup/copy the original static netcdf geo file to a unique directory and filename for comparing the original GVF monthly climatological data to the new VIIRS GVF daily data.
    a. cd $EMS/runs/<domain>/static
    b. cp *geo_em.d01.nc <NEW_USER_DIRECTORY>/geo_em.d01.nc.CLIMOGVF*
    c. Re-do step (b) for each nested domain as well (i.e., d02, d03, etc.).

7. Do a one-time edit of the file *$EMS/runs/<domain>/static/namelist.wps*
    a. Backup the original *namelist.wps* file
    b. Modify the "geog_data_res" entry to include "viirsgvf+" before the data resolution
        i. Working example #1: change "5m" to "viirsgvf+5m"
        ii. Working example #2: change "modis_lakes+modis_30s+30s" to "modis_lakes+modis_30s+viirsgvf+30s"

8. Re-localize your EMS domain(s) to incorporate the new VIIRS GVF data using existing EMS utilities
    a. **cd $EMS/runs/<domain>**
    b. **ems_domain --nogres --localize <domain>**
    c. The above command establishes the VIIRS GVF as the new static GVF for use on the run domain for future WRF model runs.
    d. Note that the **ems_domain** command should be re-run each time a new VIIRS GVF data set is acquired.

9. Template script for data acquisition and re-localization: SPoRT recommends that the data acquisition, file de-compression, and re-localization of any domains be run daily in a simple script that is invoked through the workstation's cron scheduler. A template –csh script and crontab entry is provided in Appendix A to be modified for the end-user's system.

10. Compare climatology and VIIRS GVF: The **ncview** utility that comes with the EMS installation can be used as a quick "sanity check" to validate that the higher-resolution VIIRS GVF has, in fact, replaced the default coarse-res GVF monthly climatology. As stated in step (6), it is recommended that the original *geo_em.d01.nc* or *geo_nmm.d01.nc* files be copied into a separate directory and filename (for all nested domains as well), since the EMS deletes the geo files residing in the $EMS/runs/<domain>/static/ sub-directory when re-localizing. Once you have run **ems_domain** with the new VIIRS GVF, and have two separate geo files for the original and re-localization in a separate directory outside of the EMS installation, then one can run **ncview** to display the GREENFRAC fields for comparison. As a working example, let's say that the original geo file was copied to the filename *geo_em.d01.nc.CLIMOGVF* and the VIIRS-localized geo file was copied to *geo_em.d01.nc.VIIRSGVF*. The commands to run are simply:

    ncview *geo_em.d01.nc.CLIMOGVF &*
    ncview *geo_em.d01.nc.VIIRSGVF &*

For each instance of ncview, a window will pop up that shows the variables available in the geo netcdf file, as shown in Figure 1.

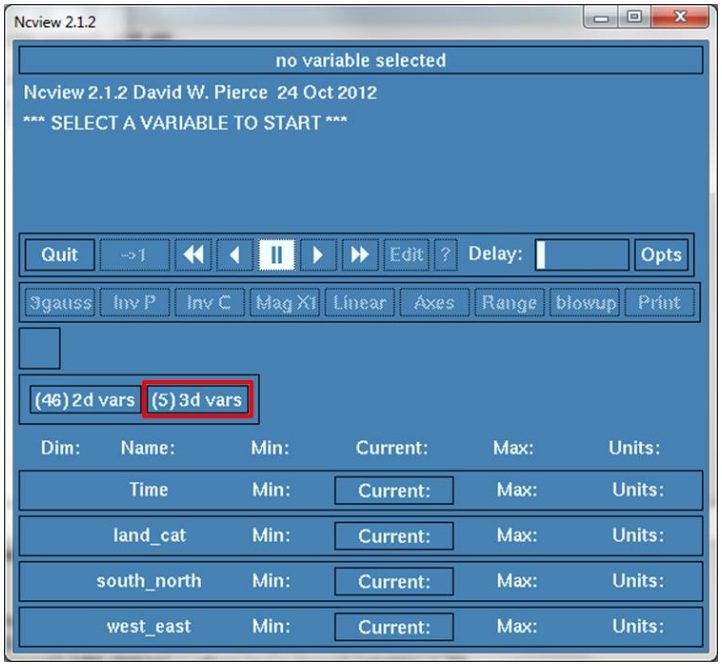

Figure 1. Pop-up window when running ncview on a given geo netcdf file generated by the EMS. The red box indicates the 3d variables under which the GREENFRAC field resides.

To view the GREENFRAC data in the ncview window, hold down the left mouse button on the "(5) 3d vars" box, and scroll down to "GREENFRAC" before releasing the left mouse button. A new window will pop up displaying the first entry in the GREENFRAC field. Additionally, the native window will update to reflect the dimensions of the GREENFRAC 3D variable, as illustrated in Figure 2. One can step through the 12 monthly displays of the GVF climatology by clicking the left mouse button on the number that intersects the "month" row and "Current:" column on the ncview navigation window (Figure 2; left).

The original GREENFRAC has 12 unique, coarse-res fields representing each month of the GVF climatology. The new GREENFRAC based on VIIRS GVF also has 12 entries, but they are all identical with the same data from the daily VIIRS GVF dataset that was used to re-localize the domain. An example GREENFRAC field for the VIIRS GVF dataset valid on 21 May 2015 is shown over the same south-central Asia domain, depicting the real-time VIIRS GVF GREENFRAC. What is immediately apparent is the marked difference in resolution between the original climatology and VIIRS GVF datasets. This distinction should be a sufficient indication that the ingestion of VIIRS GVF data is working correctly in the EMS re-localization. An additional check to ensure that the VIIRS GVF data are reasonable for the time of year is to visualize the monthly field in the climatology within **ncview** closest to the day of the VIIRS GVF, and compare the range of values between the monthly climatology and VIIRS GVF field. Keep in mind that the VIIRS GVF can and should substantially differ from the climatology at times, due to resolution differences and anomalous weather/climate regimes that affect vegetation health.

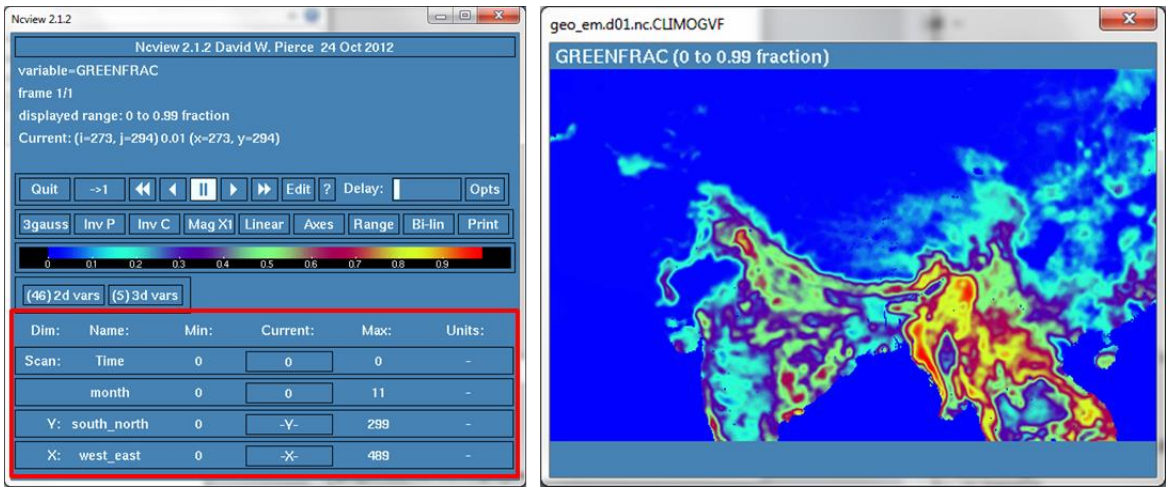

Figure 2. The original ncview window reflecting the dimensions of the GREENFRAC variable (highlighted by the red box; left), and the first GREENFRAC data entry in the new pop-up window (i.e., January; right) as shown for a south-central Asia sample domain, using the original monthly climatology data.

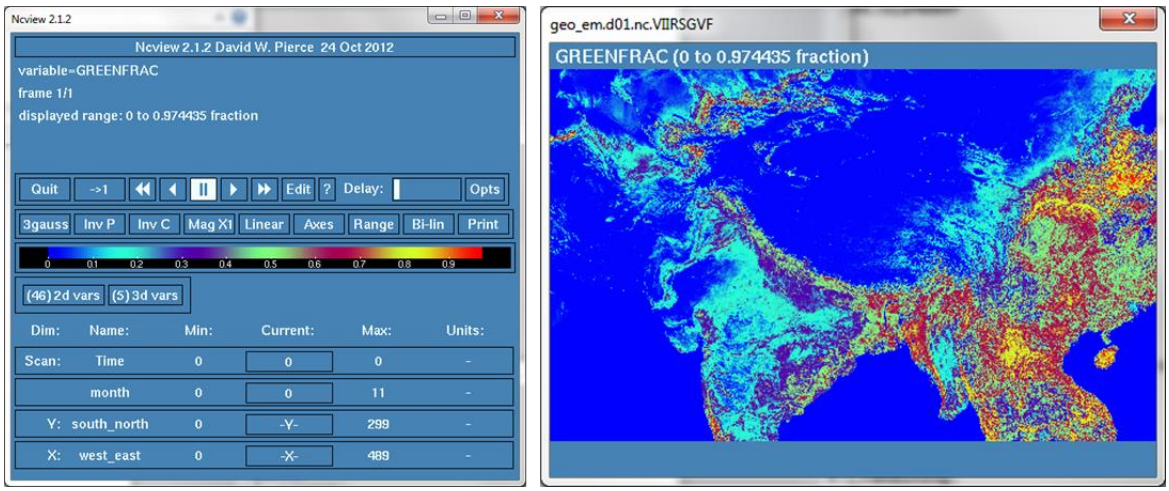

Figure 3. The ncview navigation window reflecting the dimensions of the GREENFRAC variable (left), and the GREENFRAC data entry in the pop-up window for the daily VIIRS GVF dataset valid 21 May 2015, as shown for a south-central Asia sample domain.

11. List of acronyms and abbreviations
    - ARW = Advanced Research WRF
    - EMS = Environmental Modeling System
    - GREENFRAC / GVF = Green Vegetation Fraction
    - MODIS = Moderate Resolution Imaging Spectroradiometer
    - NESDIS = National Environmental Satellite, Data, and Information Service
    - NMM = Non-hydrostatic Mesoscale Model
    - SPoRT = Short-term Prediction Research and Transition Center
    - VIIRS = Visible Infrared Imaging Radiometer Suite
    - WRF = Weather Research and Forecasting model

References:

Case, J. L., F. J. LaFontaine, J. R. Bell, G. J. Jedlovec, S. V. Kumar, and C. D. Peters-Lidard, 2014: A real-time MODIS vegetation product for land surface and numerical weather prediction models. *Trans. Geosci. Remote Sens.,* **52(3),** 1772-1786.

Case, J. L., Z. Jiang, and M. Vargas, 2015: Real-time Suomi-NPP green vegetation fraction for improving numerical weather prediction and situational awareness. Preprints, 40th National Weather Association annual meeting, Oklahoma City, OK, Natl. Wea. Assoc., AP-10. [Available online at www.nwas.org/meetings/nwa2015/extended-abstracts/2716.pdf]

Vargas, M., Z. Jiang, J. Ju, and I. A. Csiszar, 2013: EVI based green vegetation fraction derived from Suomi NPP-VIIRS. Preprints, *Ninth Symp. Future Operational Env. Sat. Systems,* Austin, TX, Amer. Meteor. Soc., P689. [Available online at https://ams.confex.com/ams/93Annual/webprogram/Paper224076.html]

Appendix A: Sample c-shell script and crontab entry for acquiring VIIRS GVF data

```
#!/bin/csh
# This sample script acquires the daily NESDIS/VIIRS GVF file, places it in the correct local directory,
# uncompresses the file, and re-runs the ems_domain localization script.
#
# Define directories:
setenv EMS SET_TO_EMS_INSTALL_DIRECTORY                    (← Modify this line)
setenv GVFDIR $EMS/data/geog/greenfrac_viirsgvf
source $EMS/etc/EMS.cshrc

# Optionally input YYYYMMDD argument; otherwise use most recent data (yesterday)
if ($#argv == 1) then
 set yyyymmdd = $1
 set gvffile = "00001-10000.00001-05000.${yyyymmdd}"
else
 set yyyymmdd = `date -u +%Y%m%d`
 set yyyymmdd = `date -u +%Y%m%d -d "${yyyymmdd}-1 days"`
 set gvffile = "00001-10000.00001-05000.${yyyymmdd}"
endif

# Change directory to where VIIRS GVF data reside
cd $GVFDIR
echo "Downloading viirsgvf file ${gvffile}.bz2"

# ftp daily VIIRS GVF data file
ftp -n geo.msfc.nasa.gov << EOF
user anonymous password myemail_address@noaa.gov           (← Modify this line)
cd SPoRT/modeling/viirsgvf/global
bin
get ${gvffile}.bz2
bye
EOF

# set and uncompress newly acquired VIIRS GVF file
echo "Un-compressing VIIRS GVF file ${gvffile}.bz2"
cp ${gvffile}.bz2 00001-10000.00001-05000.bz2
bzip2 -df 00001-10000.00001-05000.bz2

# Run ems_domain to re-localize domain(s) of interest
# Repeat for all domains of interest in the $EMS/runs directory
# as defined in the domlist variable below (space separated).
set domlist="DOMAIN1 DOMAIN2"                              (← Modify this line)
foreach dom ( ${domlist} )
  echo "Localizing domain ${dom}"
  cd $EMS/runs/${dom}
  ems_domain --nogres --localize ${dom}
end
exit
```

<u>Sample crontab entry to run at 1200 UTC daily</u>:

```
0 12 * * * Path-to-acquireScript/acquireGVF.csh >> acquireGVF.log 2>&1    (← Customize Path)
```